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HEAT TRANSFER ACROSS SURFACES IN CONTACT: TRANSIENT EFFECTS OF AMBIENT TEMPERATURES AND PRESSURES

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ABSTRACT

The time dependent effects of non constant thermal contact conductance systems are considered. In addition to a general discussion of the approach that is to be used on this new project, some results of simulated experiments are presented.

INTRODUCTION

The recent studies of contact conductance have been concerned primarily with the steady state. It is the purpose of this project to consider various types of time dependent problems when contacts are present during a heat transfer process. This knowledge may help us predict the practical consequences of contact conductance changes as well as having some possible control applications.

At this stage, we are planning and building systems for varying the contact conductance in two ways. In the first, we expect to vary the ambient pressure in a system which is at steady state. In the second method, the contact pressure in a system which is at steady state will be rapidly changed. Another phase of our current work, and in a practical way tied in with our planning of the first phase, is the computer simulation of experiments. It is with this phase of our studies that this progress report is concerned.

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COMPUTER SIMULATED EXPERIMENTS

The purposes of our computer simulated experiments are first to help us better plan the experiments which we will be carrying out and second to study the operating variables that are pertinent to this problem. The computer problem is divided into three parts. The first part (the only one reported in this study) is concerned with a number of one-dimensional heat transfer problems where the contact conductance is suddenly varied. The second part is concerned with the flow of fluids in the interstices of contacts. This work, reported briefly by Aaron and Blum (1), is being modified and expanded. The third phase of the computer work will be concerned with two-dimensional heat transfer problems where contacts are present.

In the one-dimensional experiments, we start with the system at constant temperature, suddenly change the temperature of one end, and print out distance versus temperature at different times. This is done until steady state is almost reached. At this point, the contact conductance is suddenly changed to simulate a decrease in the ambient pressure. In our experiments, this change will not be sudden since it will be limited at least in part by the ability of the vacuum system to reach low pressures. After the contact conductance is changed, the temperature is printed out again as a function of distance at various times until a new steady state condition is reached. At this point, the contact conductance is returned to the original condition which does simulate our experiments inasmuch as when the steady state condition is reached at low pressures, we will allow the gas to enter the system rapidly. When the final steady state condition is reached, the experiment will be considered at an end.

The variables which affect the results are (1) the contact conductance variation, (2) the types of materials used, (3) the length of the materials used, (4) the arrangement of the materials. In our actual experiments, we intend to use cylinders (at least initially). The computer program is a relatively simple one in which we make use of the explicit method for solving numerically the appropriate partial differential equation.

Figure 1 shows the effect of a sudden change in contact conductance on the temperature distribution on an aluminum-thorium contact. Since both the hot and cold materials are of the same length, the effect of material properties is evident. Aluminum in this case represents the higher temperature portion of the system. Figure 2 shows the effect of imposing a sudden temperature change for three systems. The overshoot occurs as would be expected when the aluminum is exposed to the higher temperature. This figure, therefore, shows the effect of materials, the effect of the placement of the material, and illustrates the existence of the overshoot in temperature drop across the contact. This is a phenomenon which we will be studying carefully during the experimental phases of this work. In figure 3, there are two major pieces of information for a given system (the aluminum-stainless steel system). The time to reach steady state is plotted against the contact conductance and the peak temperature drop across the contact which was just discussed is plotted as a function of the contact conductance. We think that the study of the nature of the peak (for example, the magnitude and the time at which the peak occurs) should prove to be helpful in understanding transient effects

We are in the process of extending this series of simulated experiments to consider the effects of different length samples with the object of obtaining generalized correlations for one-dimensional flow that we can later compare with the experiments.

ACKNOWLEDGMENT

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TABLE I

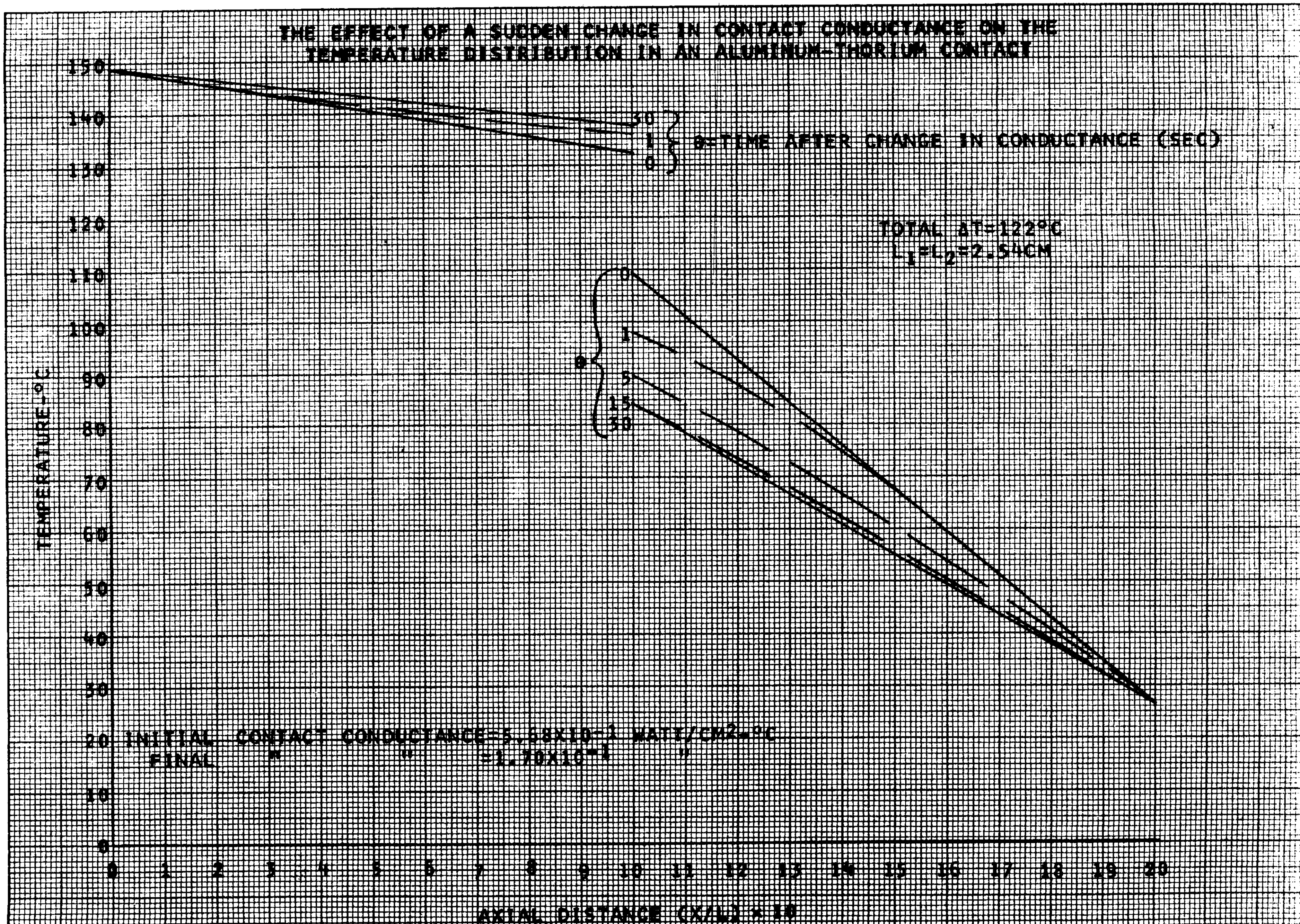
CONTACTS IN THE PRESENCE OF CONDUCTING FLUIDS

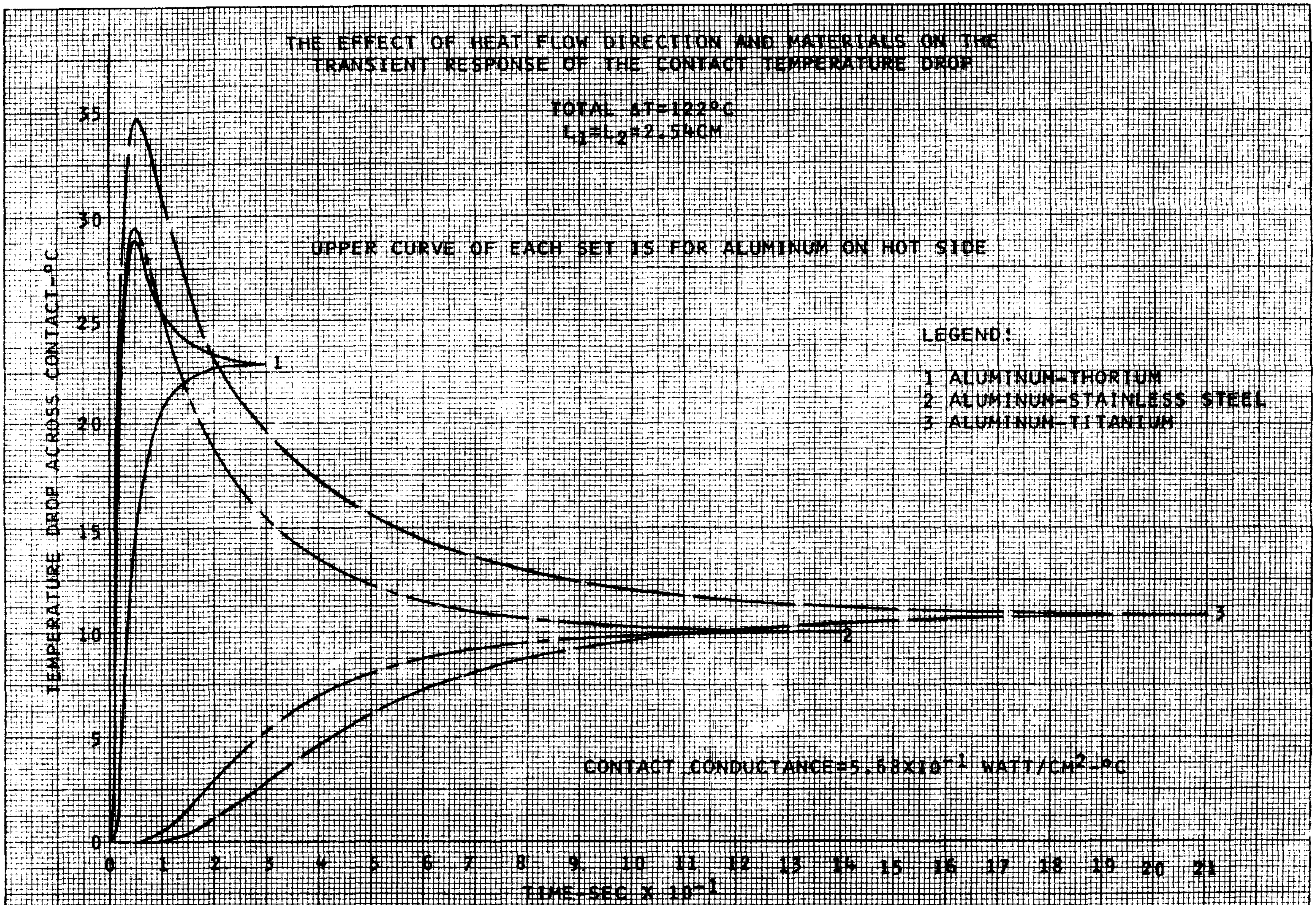
In air: 2, 3, 10, 14, 15, 16, 18, 19, 20, 27, 28, 33, 36.
In other gases: 18, 27, 31, 32, 34, 35.
With liquids in interfaces: 18, 20, 28, 30, 33, 36.
With solid materials in interface: 2, 14, 19, 31, 32, 33.
With surface roughness data: 2, 3, 14, 18, 19, 20, 27, 28, 33.
With contact pressure data: 2, 3, 5, 18, 19, 20, 27, 28, 33.
With dissimilar metal contacts: 2, 10, 18, 28, 31, 32, 35, 36.
With surface parameter theory or correlations: 3, 6, 12, 20, 21, 23.
With mean temperature level effects: 2, 14, 15, 27, 31, 33.

TABLE II

CONTACTS AT LOW PRESSURES

In air: 1, 4, 7, 8, 9, 11, 22, 25, 29, 34, 35.
In other gases: 13, 18, 31.
With solid material at interface: 4, 7, 13, 17, 20, 25.
With surface roughness data: 4, 7, 9, 11, 22.
With contact pressure data: 4, 5, 7, 8, 9, 11, 22, 29.
With dissimilar metal contacts: 13, 18, 31.
With surface parameter theory or correlations: 4, 7, 18, 22, 34, 35.
With mean temperature level effects: 4, 17, 22, 25, 29.


THE EFFECT OF A SUDDEN CHANGE IN CONTACT CONDUCTANCE ON THE
TEMPERATURE DISTRIBUTION IN AN ALUMINUM-THORIUM CONTACT
θ=TIME AFTER CHANGE IN CONDUCTANCE (SEC)
30
1
0
TOTAL ΔT=122°C
L1=L2=2.54CM
θ
0
1
5
15
30
INITIAL CONTACT CONDUCTANCE=5.68X10-1 WATT/CM2-°C
FINAL " " =1.70X10-1 "
TEMPERATURE-°C
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
AXIAL DISTANCE (X/L) × 10
FIGURE 1



THE EFFECT OF HEAT FLOW DIRECTION AND MATERIALS ON THE
TRANSIENT RESPONSE OF THE CONTACT TEMPERATURE DROP
TOTAL ΔT=122°C
L1=L2=2.54CM
UPPER CURVE OF EACH SET IS FOR ALUMINUM ON HOT SIDE
LEGEND:
1 ALUMINUM-THORIUM
2 ALUMINUM-STAINLESS STEEL
3 ALUMINUM-TITANIUM
CONTACT CONDUCTANCE=5.68X10^-1 WATT/CM^2-°C
TEMPERATURE DROP ACROSS CONTACT-°C
TIME-SEC X 10^-1
0
5
10
15
20
25
30
35
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

FIGURE 2

THE EFFECT OF CONTACT CONDUCTANCE ON TIME TO REACH STEADY STATE AND PEAK TEMPERATURE DROP ACROSS CONTACT FOR AN ALUMINUM-STAINLESS STEEL CONTACT

TOTAL ΔT=122°C
L_1=L_2=2.54CM

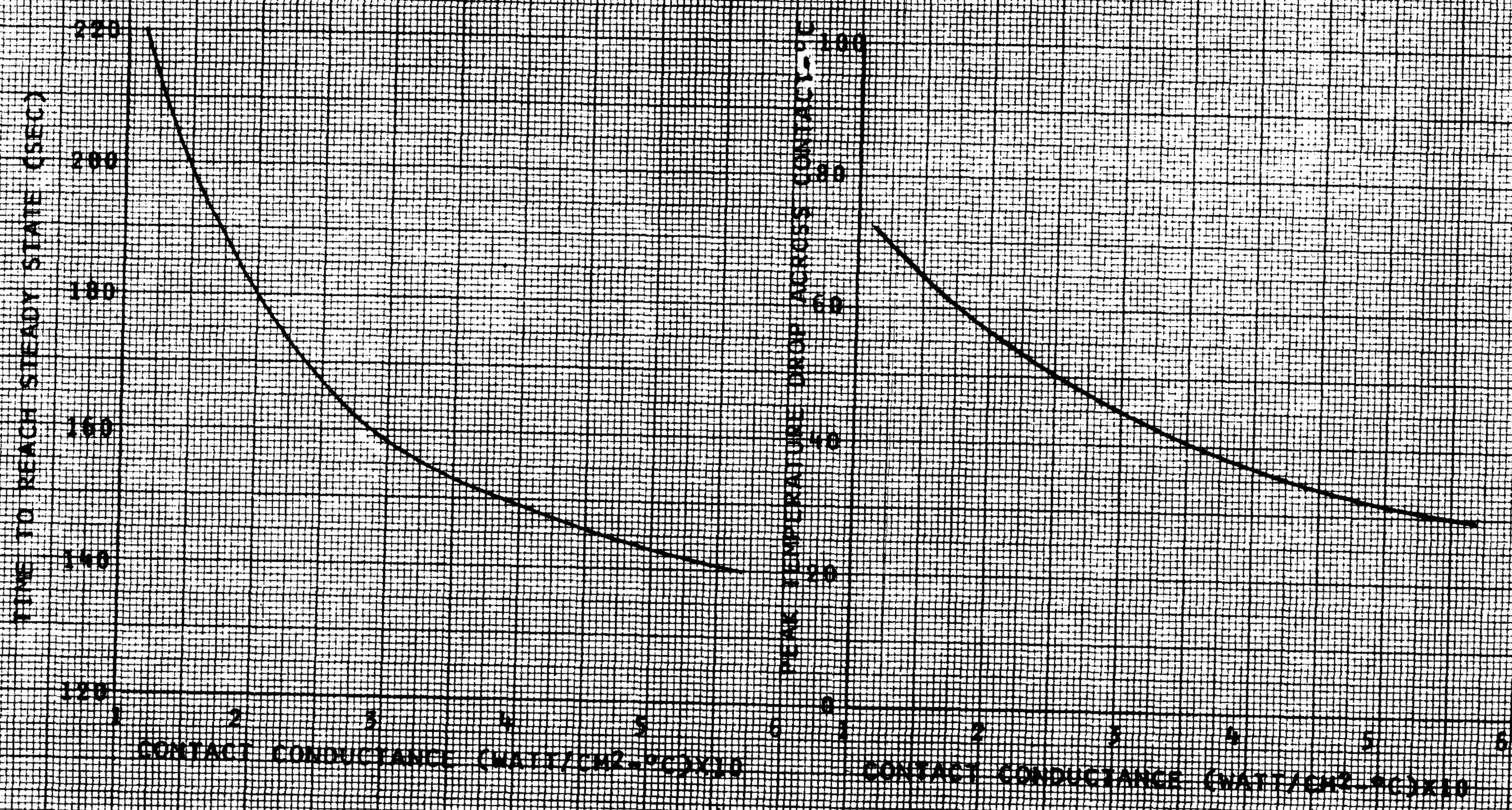


FIGURE 3